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SEMI-ANNUAL STATUS REPORT

(1 November 1964 to 30 April 1965)

Technical Report EE-124

Ahmed Erteza
James A. Doran
Donald H. Lenhert

May, 1965

This work performed for
National Aeronautics and Space
Administration under Grant
Number NsG 129-61.

The University of New Mexico
Bureau of Engineering Research
Albuquerque, New Mexico

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ABSTRACT

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This report presents a summary of the work performed under NASA grant NsG 129-61 during the last six months. This work was aimed at extending the concept of differential reflectivity to give better estimates of the surface properties (both roughness and electromagnetic) of a reflecting body. The major areas of extension are monostatic reflection from a statistically rough sphere, bistatic reflection from a deterministic surface, and reformulation of a Kirchhoff-Huygens approach into a form appropriate for use with the concept of differential reflectivity. Also presented is a short discussion of areas of future work.

Author

TABLE OF CONTENTS

1.0 Introduction

This report presents a summary of the theoretical work accomplished during the period 1 November 1964 to 30 April 1965 together with topics for future study. In the main, the purpose of the work completed and that presently continuing has been to devise means of obtaining better estimates of the electromagnetic properties of scattering surfaces, and in particular, of those scattering surfaces presently inaccessible to man. An earlier paper[1] by the authors of this report contained the development of the concept of differential reflectivity. The major portion of the work done during this report period has been toward extending the concept to: 1) back-scatter (monostatic) from a statistically configured surface and 2) scattering from a deterministic surface in the bistatic case. Special emphasis is placed on the polarization properties of the scattered fields in both cases.

2.0 Theoretical Studies

2.1 Monostatic Scattering from Statistical Surfaces

An investigation is in progress on the reflection of beam-limited radiation from a sphere with statistical roughness (i.e., a rough moon or planet) using the concept of differential reflecti-

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[1] Erteza, A., J.A. Doran, D.H. Lenhert, "Concept of Differential Reflectivity as Applied to the Reflection of Beam-Limited Radiation by a Convex Body," RADIO SCIENCE Journal of Research NBS/USNC-URSI, Vol. 69D, No. 2, February, 1965.

vity. The surface was assumed to have a guassian distribution of heights about a mean sphere and an exponential correlation function. The probability densities of the six parameters (h, h', $\frac{\partial h}{\partial \theta}$, $\frac{\partial h'}{\partial \theta}$, $\frac{\partial h}{\partial \varphi}$, and $\frac{\partial h'}{\partial \varphi}$ were found. The integral equations for the Hertizian potential vector were formulated using the differential reflectivity and then converted to $\vec{E}$ and $\vec{H}$. The restrictions on the differential reflectivity as originally derived by the authors that the angle between the surface normal and the vector to the observer could not be zero, and that the Fresnel reflection coefficients could not be complex were removed.

The expected power was obtained in integral form by the expansion of the random heights into orthogonal random variables using the Karhunen-Loéve theorem. Now in progress is the integration of the equations obtained and the ordering of the terms so that approximations can be made. Since the vector nature of the solution is maintained, the expected direct-polarized and cross-polarized power expressions are kept separate.

A report covering this work and the matching to data previously taken by other researchers will be issued during the summer.

2.2 Bistatic Scattering from Deterministic Surfaces

With the concept of differential reflectivity considered as basic, an investigation of the bistatic (source and observation points non-coincident) case of reflection from a smooth sphere has been carried out. Particular emphasis has been placed on the polarization of the scattered fields as it is expected that information relating to the electromagnetic parameters σ and ϵ of a reflecting surface may be readily obtainable from a study of the polarization properties of the scattered fields due to a known orbiting source. Vector integral expressions have been obtained for the $\vec{E}$ and $\vec{H}$ fields. Approximate evaluation in useful form of these integral expressions has been nearly completed. The results of this study will be released in a separate report in the near future.

2.3 A Kirchhoff-Huygens Approach

From a consideration of the form of the equation

$$\vec{\Pi}_r = \int_S \hat{\sigma} \cdot \vec{\Pi}_i \, ds$$

an attempt was made to re-formulate the problem of reflection of a $\vec{\Pi}$ field from an arbitrary surface as a Kirchhoff-Huygens type problem. The $\vec{\Pi}$ field at an arbitrary point was expressed as a volume integral over the current density $\vec{J}$, where $\vec{J}$ was replaced by $\nabla \times \vec{H} - \frac{\partial \vec{D}}{\partial t}$. This volume integral reduced to a surface integral over the surface enclosing the volume and a volume integral which vanished under the assumption that $\vec{J}$ was identically zero in the interior of the volume. It was asserted that a reflected $\vec{\Pi}$ field could be constructed from a knowledge of an incident $\vec{\Pi}$ field giving rise at the surface to a system of fields equivalent to a distribution of currents there. However, in addition, a knowledge of the reflection coefficients for the $\vec{E}$ and $\vec{H}$ fields at the surface was necessary in order to express the reflected fields in terms of those incident. These could be arrived at only through a solution of the exact boundary value problem and so, rather than taking recourse to approximations, the problem was temporarily laid aside. Since it appears that useful results might be forthcoming from an exhaustive investigation of this type of solution of the scattering problem, a resumption of work on it is planned at some future date.

3.0 Future Research

3.1 Continuation of Monostatic Scattering Study

The investigation described in Section 2.1 will be continued obtaining separate integral solutions for both the direct- and cross-polarized expected power. On completion of the integration, the two unknowns (i.e., variance of surface heights and correlation distance) will be evaluated for the case of the moon by comparison with lunar radar data taken by other researchers. A report covering this work will be submitted during the summer.

3.2 Continuation of Bistatic Scattering Study

Following the completion of the study of scattering from a smooth sphere as discussed in Section 2.2, it is intended to apply similar techniques to targets of other than spherical shape. Study will be made of the transient case as well as of the steady state one. In addition, a study will be made of the doppler effects on the scattered radiation as a result of motion of the source relative to the target. The situation here is that of a transmitter of known characteristics orbiting a body such as the moon with the observation point being situated on the earth. Should promising results ensue from this investigation it is planned to submit a proposal to NASA for an experiment along these lines.

3.3 Acoustic Scattering from Surfaces

This topic is carried over from the last report. No work was accomplished in the area during this report period due to concentration in other areas. However, additional personnel will be added during the summer months to work on the problem. Using the concept of differential reflectivity an investigation will be made of the acoustic scattering of a spherical wave from a surface. The purpose is to obtain better justification than exists at present for the use of the acoustic simulator to determine electromagnetic scattering from a surface. Presently, the use of the acoustic simulator is justifiable only on targets for which electromagnetic scattering has been experimentally measured. If the longitudinal pressure waves reflected from a particular surface can be related to the direct polarized component of electromagnetic reflections, then theoretical methods of determining electromagnetic reflection can be verified by the use of the acoustic simulator and possibly extended to cases which would otherwise require the use of large digital computers for numerical evaluation of certain integrals. Any results obtained which take into account body effects (i.e., due to setting up of transverse and longitudinal waves inside the target) will be of considerable importance in the study of the corresponding electromagnetic cases.

4.0 Travel

The following trip was made by research personnel for the purpose of discussing research work, attending technical conferences and exchanging research notes with other people in this and allied fields.

Mr. D.H. Lenhert attended the spring URSI-AGU meetings at the National Academy of Sciences, Washington, D.C., in April, 1965.